Integrated Pest Management Practices for the Light Brown Apple Moth in New Zealand: Implications for California

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ABSTRACT

The Light Brown Apple Moth, *Epiphyas postvittana* (LBAM) has been an established exotic species in New Zealand for more than 100 years. The authors conducted a three-week, 3,000-kilometer fact-finding study in New Zealand's two major agricultural regions to assess integrated pest management (IPM) of LBAM and applicable strategies for California. LBAM was considered a problem pest in New Zealand orchards during the 1980s when regular, calendar applications of broad-spectrum organophosphate pesticides had eliminated the beneficial insects that prey on LBAM. However, since elimination of organophosphate treatments in 2001 and subsequent restoration of populations of beneficial insects and other organisms, LBAM is considered a minor pest that does not cause economically significant crop damage or have detrimental effect on native flora. Today, LBAM is effectively controlled almost exclusively by natural predators in both agricultural settings and wild lands in New Zealand. There is no evidence of biological or environmental threat from LBAM in New Zealand. Because of United States' zero-tolerance quarantine requirements for LBAM, New Zealand horticultural/agricultural professionals use pheromone sticky traps to monitor LBAM populations and, based on monitoring data, timed ground applications of insect growth regulators (IGRs) are used in select agricultural settings to prevent shipments from being rejected for export to the U.S. The success of New Zealand agriculture and horticulture professionals in controlling LBAM and other leaf-roller pests using IPM techniques and few or no chemical applications is a model of best IPM practices that can be readily adopted in California to control LBAM, particularly because many of the natural LBAM predators that are present in New Zealand are also found in California. Adopting IPM best practices would include suspending planned aerial and ground treatments for LBAM in California and monitoring to determine extent to which LBAM populations are being parasitized or destroyed by predators. United States Department of Agriculture (USDA) classification of LBAM as an actionable quarantine pest should be reviewed and revised based on current, relevant, science-based information. The negative impact of organophosphate use on beneficial predator species in New Zealand, along with the known health and environmental dangers of these chemicals, suggests that current requirements for organophosphate controls for LBAM in nurseries and elsewhere in the U.S. should be abandoned.

Introduction

This report describes results of a January 2008 fact-finding study on integrated pest management of the Light Brown Apple Moth (LBAM) in New Zealand. The study was undertaken to understand the extent of LBAM's effect on New Zealand's agriculture and natural environment and the methods of managing LBAM, with the goal of understanding potential impacts of and best management practices for LBAM in California. The authors focused on understanding best management practices for control of LBAM and how these strategies impact the cultivation of plants in botanical collections in gardens and arboreta as well as in commercial nursery and agricultural cropping systems.

New Zealand was chosen for this research because its climate and crops are similar to California's coastal farming areas and because LBAM was introduced to New Zealand from Tasmania and first reported in New Zealand in 1891 (Thomas, 1987, HortNet http://www.hortnet.co.nz/key/keys/info/distrib/lba-dist.htm) and thus has been an established exotic in New Zealand for more than 100 years.

The remainder of this report describes the study's research methods and presents findings and discussion on LBAM biology and behavior, hosts, populations, damage, and control in New Zealand, as well as LBAM's role in global trade of New Zealand agricultural products.

Methodology

The authors traveled and conducted interviews with government, agricultural, and horticultural entomologists and researchers of LBAM and insect pests as well as wholesale and retail agricultural and horticultural producers and plant conservationists. They also conducted field searches for LBAM presence and damage in commercial agricultural fields, orchards, native habitats including Abel Tasman National Park, and along roadsides. The research was carried out over a period of three weeks, January 4 - 29, 2008, which is mid-summer in New Zealand when LBAM would be expected to be active in all life stages and readily observable. The goals of the research were to learn from agriculture, integrated pest management (IPM), entomology, and conservation experts about LBAM in New Zealand and to identify IPM strategies that would be effective against LBAM in California.

The authors focused on the two main agricultural production areas of New Zealand: on the North Island, the Hawke's Bay region, known as the "fruit basket " of New Zealand where the major produce is apples, nectarines, kiwis, wine-grapes and assorted row-crops; and on the South Island, the Nelson agricultural region, which is a major production area for apples, currants, hops and wine-grapes. See Figure 1.

Figure 1. New Zealand map

Both the Hawke's Bay (Napier) and Nelson areas are similar in terrain and mixed forest areas to California's Monterey Bay and Santa Cruz areas where the California LBAM presence is most dense. The Hawke's Bay region is a bit warmer and moister than Monterey Bay, making it an ideal climate and study area for LBAM. These agricultural regions also have a long history of studying and controlling LBAM and have developed technologies to best protect crops. As shown in Table 1, Nelson and Napier have climates very similar to California's Central Coast.

Comparison of Temperature Ranges, Average Mean Temperatues and Precipitation in Monterey, California and Napier, New Zealand in 2007. Months have been aligned to season.

2007	January	February	March	April	May	June	July	August	September	October	November	December
Santa Cruz, California												
Temperature Range (F)	39 / 61	41 / 63	42 / 65	43 / 68	46 / 71	49 / 74	51 / 76	52 / 76	50 / 77	47 / 74	43 / 66	36 / 69
Average Temperature (F)	48	52	54	53	55	58	62	62	63	59	56	51
Precipitation (inches)	6.4	5.5	4.5	2.2	0.7	0.2	0.1	0.1	0.3	1.3	3.5	0.69
	July	**August**	**September**	**October**	**November**	**December**	**January**	**February**	**March**	**April**	**May**	**June**
Napier, New Zealand												
Temperature Range (F)	36 / 65	35 / 66	33 / 67	34 / 77	43 / 83	48 / 83	45 / 89	47 / 86	46 / 85	38 / 75	30 / 72	31 / 69
Average temperature (F)	50	50	52	58	58	64	66	64	65	54	55	49
Precipitation (inches)	3.3	3.2	2.1	2.2	1.6	2.9	1.8	2.2	2.7	2.5	0.14	3.6

Source: http://www.wunderground.com, http://worldclimate.com

Table 1. Comparison of Santa Cruz, CA and Napier, NZ Temperatures and Rainfall

The southernmost area of New Zealand was not visited because its colder, harsher climate is both less hospitable to LBAM than the warmer climate farther north and dissimilar to the climate of areas where LBAM is presently found in California.

In addition, New Zealand cultivates hundreds of thousands of hectares of Monterey pine (*Pinus radiata*) and has planted many Californian species including vintage Monterey cypresses (*Cupressus macrocarpa*), giant sequoias (*Sequoiadendron giganteum*), coastal redwoods (*Sequoia sempervirens*), as well as native New Zealand conifers.

Results and Discussion

The subsections below present findings related to LBAM, its biology, behavior, enemies (beneficial control agents), populations, damage, control in New Zealand, and role in New Zealand agricultural trade.

Biology and Behavior of LBAM

LBAM is a tortricid (Tortricidae) moth and a member of the leaf-roller moth family in the order Lepidoptera. Each LBAM individual exhibits four life stages: egg, olarva, pupa, adult (moth). LBAM is polyphagous, meaning that it is not host specific but rather feeds on a variety of plant species. A superficial feeder as a larva (see Figure 2), LBAM typically causes cosmetic damage to the surface of leaves and fruit and only rarely penetrates a host fruit. LBAM does not defoliate plants. Defoliation is contrary to leaf rollers' biological need for leaves that, with the help of thread material, the larvae roll around themselves for protection. The rolled leaves provide protection from predators and the ideal conditions for growth and development. Like all leaf rollers, LBAM is subject to natural predation and parasitism. Major predators and parasites in New Zealand include: birds, spiders, wasps, flies, beetles, lacewings, and earwigs to name only a few. A full listing of enemies to LBAM can be found at: http://www.hortnet.co.nz/key/stone/info/enemies/lba-enem.htm

LBAM may mate up to three times during its 1- to 1.5-week lifespan in New Zealand. Female moths typically lay 30-50 eggs per egg mass. The majority of the eggs are subject to environmental pressures including predation or parasitism before reaching adulthood and thus do not mature (HortNet Website at http://www.hortnet.co.nz/publications/proceedings/ifoam/ifoam69.htm)

Adult LBAM travel an average of approximately 100 meters from their hatching sites during their lifetimes and are not necessarily particular about where oviposition (egg-laying) occurs. The larvae can travel mostly downward by silken threads. Any larva that falls or loses contact with its food source/host plant have little chance of survival, so the larvae stay connected to the plant by the silken thread. Adults move the greatest distances (for dispersal of the populations). LBAM does not form a central colony that can spread and cause detrimental effects in an agricultural field. Because it is polyphagous, LBAM can disperse and survive without concentrating and adversely affecting all plants in a concentrated area.

Figure 2. Superficial leaf damage from LBAM larva

LBAM Hosts and Populations in New Zealand
Although LBAM is considered by New Zealand HortResearch, the government agricultural and horticultural research agency, to be "common" in orchards throughout New Zealand and "less common, rare, or even absent" in areas of New Zealand still covered in native forest (HortResearch 2008 http://www.hortnet.co.nz/key/keys/info/distrib/lba-dist.htm), LBAM is, in fact, difficult to find in New Zealand. Eighty to ninety percent of LBAM larvae are parasitized by natural predators before maturation (Shaw, 2008). According to New Zealand Ministry of Agriculture and Food (MAF) and Department of Conservation (DOC) experts, LBAM does not build up in any one host in the wild and has never posed a threat to native forests. Natural predators keep LBAM in check, and it is so rare in the wild that it requires a true expert and meticulous searching to even find any sign of it. For meeting U.S. quarantine requirements, LBAM populations in New Zealand are estimated and monitored using pheromone traps.

LBAM is not an insect of significance in Monterey pine plantations in New Zealand. LBAM is a leaf-roller moth that requires flat-surfaced leaves to protect larvae while they mature. Clearwater (2008) notes that LBAM clearly does not have a preference for gymnosperms and is not considered a pest of these plants in New Zealand.

Shaw (2008) reports that gorse is a preferred LBAM host plant in New Zealand; however, the authors found no LBAM larvae on gorse in a wide variety of regions in the North Island and the main agricultural regions of the South Island. In fact, the authors' extensive search for LBAM in native New Zealand habitats during the three-week, 3,000-km extent of this research trip revealed only a few larvae, one on an exotic planting in a hotel garden, as well as a few tortricid moths flying around porch lights in the evening. No evidence of LBAM eggs, larvae or adults was found in the 22,530-hectare Abel Tasman National Park on New Zealand's South Island. This national park has a mixture of native and non-native plant species with a multi-story diverse habitat of broadleaves, ferns and conifers.

Agricultural/horticultural researchers in New Zealand noted that, because LBAM larvae are often parasitized, finding a larva does not mean that a viable adult LBAM will hatch. If a parasite has laid eggs in the larva, the parasite's adults, e.g., wasps, flies will hatch rather than LBAM. Due to the need to understand natural controls for LBAM in California and the similarity of types of organisms keeping LBAM under control in New Zealand with those already present in California, monitoring of levels of parasitism of all life stages should begin immediately for LBAM in California. As noted below in the *LBAM Control in New Zealand* section, researchers in New Zealand have developed a monitoring protocol that allows them to determine the extent of parasitism of LBAM populations to prevent unnecessary and costly control efforts based on observation of larvae only. Similar parasitism of LBAM is likely occurring in the regions of California where it is present. The Arboretum at the University of California, Santa Cruz has initiated a survey of beneficial insects that may control LBAM. In eight larvae raised to adults, two have been parasitized by natural predators.

LBAM Damage in New Zealand

LBAM is currently considered a minor biological pest in New Zealand agriculture, including apple, peach/nectarine, citrus, and vineyard crops. Codling moth ("the worm in the apple," also a tortricid) and woolly apple aphids are much more significant pests in apples, and thrips and mites are the pests of significance in New Zealand citrus (Videan 2008)

Hawkes Bay horticultural researchers report that, with no monitoring or treatments and if LBAM were uncontrolled other than by naturally occurring trichogramma or other beneficial insects and organisms, the maximum damage caused by LBAM would be one percent or less of crops (Walker 2008).

Reports of damage to crops prior to 2001 in Australia or New Zealand are from the era when organophosphate pesticides were heavily used to control LBAM (to comply with USDA requirements that no trace of LBAM be found). These pesticides eliminated LBAM's natural predators. Once organophosphate use stopped in 2001 and natural predator populations rebounded, New Zealand's LBAM problem was greatly reduced to its current, insignificant level.

New Zealand horticulture and agriculture professionals so successfully use IPM strategies to manage LBAM that in more than 3,000 U.S. shipments of pome (pip) fruit in 2006, only six were rejected. One positive LBAM find can cause rejection of a single 15-ton fruit order (Walker 2008). Thanks to exceptional, modern New Zealand IPM practices, leaf rollers have limited economic impact on fruit or crop production other than occasional shipments rejected by U.S. only because of zero tolerance for LBAM.

LBAM Control in New Zealand

Beneficial insects are considered the first and best line of defense against leaf rollers, and insect growth regulators (IGRs), which are based on derivatives from natural sources, are the primary insecticide used for leaf roller and codling moth control in New Zealand. Growth regulators do not negatively affect beneficial insects to any significant degree. Rather, IGRs are relatively target-specific and cause target larvae to mature faster than normal before the larvae are physiologically ready and so die.

To control LBAM effectively with IGRs, it is important to target overwintering LBAM populations. As cooler weather progresses, adult populations of LBAM drop; adults die off, and larvae do not morph into adults. The lowest adult numbers occur in late winter. IGRs are most effective when applied as eggs hatch and larvae begin to feed in warmer summer weather. In California, IGRs should probably be applied in May, but the timing needs to be verified by phenological monitoring using pheromone traps for adult males (Shaw 2008).

Treatments with least-toxic IGRs for most other pests, particularly codling moth, which is one of the top apple pests in New Zealand, generally act, along with beneficial insects, as adequate LBAM controls. Biocontrols are effective against all LBAM life stages: eggs, larvae, pupa, and adults. Biocontrols include native and introduced wasps and native tachinid (Tachinidae) flies. The key to effective control with predators and parasites is to encourage a range of insects attacking all life stages.

In the Nelson area, roughly four to 10 percent of producers are organic. Because organic systems encourage beneficial insect populations and do not negatively affect beneficial organisms and insects with the use of harsh chemical controls, pests (including LBAM) are not significant problems for localized organic producers.

The leaf-roller complex, including LBAM and other native New Zealand species, is readily monitored in the early to mid-spring with a pheromone sticky trap and regular visual inspection. Based on monitoring results, a single IGR spray regime can be effective for season-long control. Growers in the Hawke's Bay and Nelson regions do not use mating disruption pheromones to control LBAM. They monitor in late spring with pheromone traps specific to LBAM and codling moth. If the trap counts warrant, an IGR is applied (e.g. Intrepid, Confirm: methoxyfenozide, tebufenozide). This timed treatment adequately suppresses LBAM and codling moth populations for the year (Walker 2008, Shaw 2008).

Pyrethroids (natural or synthetic) are effective controls for LBAM but also are detrimental to beneficial insects and pollinators, making these products undesirable for long-term IPM of LBAM. Pyrethroids are especially detrimental to native and introduced (honeybee) bee populations essential for pollination and to mammals.

History of Organophosphate Control

During the late 1980s and 1990s, organophosphates were applied regularly in New Zealand orchards with no monitoring for insect populations. The effort was to create a "sterile nursery" situation where there were no pests and no beneficial insects. Organophosphates were used because of the zero tolerance for LBAM in produce to be exported to the U.S. The chemicals were applied on a schedule rather than in response to pest populations. Under the organophosphate spray regime, LBAM was a problem of greater significance than it is today, and all pests were more difficult to control and became increasingly hard to keep in check. Populations of insects, including LBAM developed resistance to the organophosphate formulation.

Use of organophosphates was eliminated in New Zealand in 2001. HortResearch experts report that once the use of broad-spectrum organophosphates was stopped and agricultural professionals began monitoring for LBAM and timing IGR sprays, all of which allowed beneficial insects to affect LBAM populations, the LBAM problem reduced dramatically so that the moth is now considered a minor pest (except for the challenge posed by the U.S. Department of Agriculture quarantine) http://www.hortnet.co.nz/key/stone/info/control/lbacontr/lr-chem.htm. Organophosphates were destroying beneficial insects and creating resistant insects, and orchards and vineyards were becoming LBAM breeding grounds.

Shaw (2008) reports that, at Nelson/ Motueka, "control trees with no insect or chemical controls used have not recorded any damage from LBAM or other leaf rollers for more than 10 years." HortResearch staff attempted to force LBAM infestation of these trees by introducing LBAM eggs and larvae into the trees to no avail. Any infestation of these trees by LBAM was quickly controlled by native predators without the need for IGRs. "Once organophosphates were removed from the system and populations of beneficials were left to develop naturally, complete control of LBAM was realized in less than 5 years" (Shaw 2008). When organophosphates were compared to natural controls in consistent blocks of apples, control of LBAM was achieved with natural controls in less than two years. Organophosphates never allowed effective control, and LBAM developed resistance to them.

It is worth noting that in New Zealand, intercropping has been shown to promote beneficial insect populations, resulting in near-complete LBAM population suppression to below thresholds for use of control measures (Irvin et al. 2006, Begum et al. 2006)

Monitoring

Spring populations of LBAM in monitoring traps in total numbers per month is key to deciding whether to use IGRs to control the population. Local monitoring of population levels allows tracking of seasonal fluctuations (Shaw 2008).

Monitoring programs should assess levels of LBAM phenologically (at various life stages and, by rearing larvae and eggs from host plants, the degree of predation and parasitism of LBAM. Parasites and beneficial controls may not be seen in early-stage occupation of habitats by LBAM or other invading pests but will develop as the predators respond to the presence of LBAM as a possible host.

A monitoring protocol has been developed that allows determination of the rate of parasitism of LBAM larvae. Auckland HortResearch Insect Rearing Lab uses a general-purpose diet to rear LBAM larvae so that they can be observed to see if they are parasitized. Larvae are placed in a capped tube with cotton, allowed to develop at room temperatures, and observed to determine whether LBAM develops normally, parasites hatch, or development is adversely affected by other potential control means.

The specifics of monitoring and thresholds for treatment are provided on the New Zealand HortResearch website: http://www.hortnet.co.nz/key/.

Eradication and Pheromone Use

Widespread LBAM eradication efforts have never been attempted in New Zealand. A very limited eradication program took place during the 1980s affecting two orchards (200 hectares total) in the Nelson region where an insecticide-resistant LBAM strain had appeared. Twist-tie pheromone strips (1000 per hectare) and ground-applied insecticides were used to eradicate this resistant and localized LBAM population. Eradication is very difficult unless a population is quite limited and well defined.

New Zealand researchers report that effective mating disruption using pheromones will only work under the following specific conditions:

Extensive, even, and complete coverage of the pheromone
Uniform blocks of a single crop (single canopy height)
Uniform topography (no slopes, hills or valleys)
Low population density of target pest (not too concentrated)

Under the above conditions, twist ties can be used for control under extensive coverage. However, pheromones applied by any means cannot be effectively used across large diverse areas with varying canopy heights, mixed species composition, and varying terrain areas.

New Zealand researchers also note that aerial pheromone spraying interferes with monitoring using pheromone traps, and monitoring is critical to successful control. Moreover, use of broadcast pheromone spray to eradicate or control the moth is not effective because female moths issue a more concentrated scent plume than the dispersed pheromone scent of an aerial spray application, so male moths are able to find the females (Shaw 2008).

Until tests reportedly carried out under a U.S. government contract in 2008 in southern New Zealand forests (“NZ Forest Provides Laboratory for Pheromone Trials” 2008 http://nz.news.yahoo.com/080217/3/p/40zs.html), pheromones had never been aerially applied in New Zealand. These trials are been undertaken within a Monterey Pine plantation and does not involve applying the pheromone over urban areas. Pheromones have never been used for widespread eradication anywhere in the world.

HortResearch stations on both islands agree that eradicating LBAM in California and anywhere would require extensive, widespread use of IGRs with repeated applications to address elusive, selected populations. These experts also question the efficacy of *bacillus thuringiensis* (Bt) against LBAM. Bt can also have a detrimental effect on beneficial insects. They report that IGRs do not harm populations of beneficial insects and that IGRs persist on foliage much more effectively than organophosphates did. Larvae emerging from eggs begin to perish as soon as they start feeding on the growth regulators. Tests show IGRs are ovicidal as well as larvicidal and not toxic to predatory/beneficial insects. The beneficial effects of the application of growth regulators can be seen one to two days after application (Walker 2008, Shaw 2008).

LBAM and Global Trade of New Zealand Agricultural Products

LBAM is not of biological concern on either island in New Zealand but remains a pest of concern only because it is a quarantine pest for exports. USDA considers LBAM an "actionable quarantine pest" and has zero tolerance for LBAM finds in pre-inspection of U.S.-bound fruit shipments. Consignments rejected because of any LBAM life stages are sent to non-U.S. markets, e.g., Europe, which does not have phytosanitary restrictions for LBAM. Today very few New Zealand fruit shipments are rejected by the U.S. (Walker 2008), which further suggests that New Zealand growers' LBAM controls relying on natural predators and IPM strategies are successful.

HortResearch experts say that when USDA announced during the late 1990s that the U.S. would no longer accept fruit treated with organophosphates because of concerns for the safety of fruit handlers and consumers, this was the catalyst for abandonment of organophosphates and the move to reliance on natural predators and IPM methods.

Implications for California

The information on LBAM and IPM in New Zealand reported in this report has significant implications for addressing LBAM in California.

First, it is worth noting that, according to the National Museum of Natural History Catalog of Type Specimens of Tortricidae (www.sel.barc.usda.gov/lep/tort_types_list.html), California has 85 native and localized North American species of tortricid moths; none are problematic as a pest. All are kept in check by natural biological controls, so there is confidence to believe that LBAM will also be controlled by native natural predators or parasites. Preliminary studies by the California Department of Food and Agriculture report a high level of parasitization of LBAM larvae by native California trichogramma wasps. Entomologists speculate that LBAM may have been in California for as long as a decade already (Garvey 2007), so it is possible that LBAM is already being controlled by natural predators. Many LBAM predator species in New Zealand are the same or closely related to California species (birds, earwigs, viruses, trichogramma and other wasps, tachinid flies, spiders, beetles, etc.).

According to New Zealand information, the pheromone treatment currently proposed for LBAM will most likely not eliminate nor control LBAM because none of the essential conditions for successful pheromone use can be met. Use of the pheromone cannot be complete (e.g., it cannot be applied over sanctuary buffer zones and along streams/waterways), the pheromone will not be applied over a uniform block but rather over mixed forests and native vegetation, houses, schools, roadways, crops, and ornamental gardens. Moreover, topography of the California coast is highly varied and diverse, and LBAM populations in these areas are dispersed and, in areas of high trapping numbers, are too concentrated for effective use of mating disruption pheromones. In addition, application of mating disruption pheromone alone without the addition of IGRs would not allow for success.

Current CDFA requirements that commercial nurseries in California use the organophosphate insecticide chlorpyrifos if LBAM larvae are found are in direct contradiction to New Zealand findings that organophosphates destroy LBAM's natural predators, resulting in resistance developing in LBAM populations. New Zealand experts recommend use of IGRs in the control of LBAM in agricultural systems as much safer and more effective.

Monitoring should be performed to assess level of predation on LBAM larvae, which could reveal data indicating that less (or no) intervention is required to control LBAM in California.

Conclusions

The success of New Zealand agriculture and horticulture professionals in controlling LBAM and other leaf-roller pests using IPM techniques and few or no chemical applications is a model of best IPM practices that can be readily adopted in California to control LBAM, particularly because many of the natural LBAM predators that are present in New Zealand are also found in California.

The finding that there is no evidence of biological or environmental threat from LBAM in New Zealand, which has climate and crops much like California and where LBAM has been an established exotic for more than a century, bodes well for the ability of California agriculture and ecosystems to accommodate to LBAM's presence and suggests that USDA classification of LBAM as an actionable quarantine pest should be reviewed and revised. USDA's pest quarantine list needs to be re-evaluated based on current, relevant, science-based information.

New Zealand researchers say that it will be very problematic to attempt to eradicate this insect as it has now been firmly established over an extensive and diverse area. In California, LBAM is found across more than 7000 square miles of varied terrain and conditions, including within protected buffer zones and sensitive riparian corridors.

The negative impact of organophosphate use on beneficial predator species in New Zealand, along with the known short- and long-term health and environmental dangers of these chemicals, suggests that requirements for organophosphate controls for LBAM in the U.S. should be abandoned. The requirement that California nurseries use chlorpyriphos sets California up for failure of long-term LBAM management and management of future pests that would otherwise be controlled by natural predator species that will be compromised or eliminated by chlorpyriphos use. This and other highly toxic treatments need to be discouraged or prohibited in commercial nurseries. The short- and long-term risks to exposure of organophosphates and the long-term persistence of organophosphates in the environment make their continued use for control of LBAM inadvisable.

A realistic assessment of LBAM populations and potential damage based on New Zealand data must rely on recent studies published after the use of organophosphates stopped. Organophosphate use causes an unnatural situation to develop in which natural predator populations are unable to function.

There may not be any need to introduce a non-native control for LBAM in California; natural controls may already exist in the native fauna given the robust numbers of native Tortricidae in California.

Summary of Recommendations
Based on the findings above, the key recommendations of this report are to:

- Suspend planned aerial and ground treatments for Light Brown Apple Moth (LBAM) in California and monitor to determine extent to which LBAM populations are being parasitized or destroyed by predators.

- Adopt IPM best practices from New Zealand to control LBAM if necessary.

- Review USDA classification of LBAM as an actionable quarantine pest based on current, relevant, science-based information.

- Eliminate requirements for organophosphate controls for LBAM in the U.S to protect natural predator species that feed on LBAM and other pests.

- Realistically assess the potential impact of LBAM in California using New Zealand data published since the use of organophosphates in New Zealand stopped.

<u>Sources</u>

The information in this report comes from the authors' consultation with the following researchers and agricultural experts in New Zealand:

Jim Walker, PhD, Technical Research Scientist, New Zealand HortResearch

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REFERENCES

Begum et al. 2006. Using selective food plants to maximize biological control of vineyard pests. Journal of Applied Ecology, 43: 547-554.

Garvey, K. K. 2007. "Entomologists Targeting Light Brown Apple Moth." University of California News. http://www.universityofcalifornia.edu/news/article/9323

Irvin, N.A., S.L. Scarrett, S.D. Wratten, C.M. Frampton, R. B. Chapman, and J.M. Tylianakis 2006. The Effects of floral understoreys on parasitism of leafrollers (Lepidoptera: Tortricidae) on apples in New Zealand. *Agricultural and Forest Entomology* 8, 25-34.

"NZ forest provides laboratory for pheromone trials" 2/17/08; http://nz.news.yahoo.com//080217/3/40zs.html

Thomas, W.P. 1987. *A Review of Biological Control of Invertebrate Pests and Weeds in New Zealand 1974 to 1987*. Emerson, P.J., R.J. Hill, J. Bain, and W.P. Thomas. Wollingford: CAB International.

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